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March 31, 1999

To: Mr. John Yearsley, Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington

From: Dave Wegner
Ecosystem Management International, Inc.
Principal Scientist

Subject: Review Comments of Technical Report
Columbia River Temperature Assessment: Simulation Methods

I have received and reviewed the technical report entitled ***Columbia River Temperature Assessment: Simulation Methods***. I have reviewed the documentation that you provided and have evaluated your approach, assumptions and results based on my experience and historic application of thermal models in the Colorado River basin.

My review follows the following outline and represents the major areas that your report addresses. My review approach has focused on three primary representations.

- Conceptual Representation - has the logic for development of the model been adequately laid out and are the steps for application clearly defined?
- Functional Representation - has the formulation of the model, specifically the physical constraints, process, variables, and boundary conditions been adequately defined?
- Computational Representation - does the model adequately translate the logic into correct mathematical forms and procedures necessary for solution of the problem over the desired temporal and spatial spectrum?

My primary expertise lies in the evaluation of the Conceptual and Functional representation arenas. These two areas must be credibly and accurately defined if an accurate assessment is to be completed on the thermal conditions in the Snake and Columbia Rivers.

MODEL PEER REVIEW FOCUS QUESTIONS

Part I. Conceptual Model

(1) Have the objectives of the temperature model been clearly identified?

In general yes. Additional clarification is needed in regards to who will be using this model, what level of detail is required in their use, and if this model will be used to set TMDL limits.

(2) Has the level of certainty required by the model objectives been identified and can the proposed concept achieve this level of certainty?

In regards to the objective of developing a screening model, this assessment has achieved its goal. Applications above the screening level however require additional clarification, statistical analysis and a more rigorous assessment of the error bias.

(3) Have the appropriate system boundaries, time scales and length scales been identified?

For a screening model assessment the appropriate boundaries and scales have been identified in general except for inclusion of addressing the boundaries related to reservoir dynamics behind the study dams. This area needs to be expanded upon (see comments below).

(4) Have the important source terms and background conditions been identified and are there adequate data to characterize them sufficiently for the model application?

In general yes. The assessment does a good job of identifying the necessary model parameters and the data necessary for application. The boundary conditions for the reservoir and pre-project thermal and flow conditions however should be further articulated.

(5) Are the available data adequate for achieving the levels of certainty required by the model objectives?

For a screening level model the answer is yes.

Part II. Model Development

(1) Is the model being developed based on current knowledge and do the mathematical descriptions accurately reflect the processes identified in the conceptual model?

Yes, the model is based on the present state of the art.

(2) What structural properties in the model cold affect reliability of model predictions?

- Reservoir limnology is not dealt with directly and should be.
- The physical geometry needs to be beefed up for any level of analysis beyond the screening level.
- System, both physical and limnological, variability is not addressed adequately for anything beyond a screening level approach.
- The statistical significance of the results has not been addressed and should be before the report is finalized.
- Temporal and spatial variability should be discussed as related to implications to model results

(3) Is the parameter estimation process reasonable in terms of available data and knowledge?

For a screening level assessment the answer is Yes.

(4) Is there a well designed plan for determining if and when the model is acceptable for use as a decision-support tool?

A rigorous statistical evaluation of the results is necessary before providing this tool to decision-makers. Additionally an assessment on how this model should be used must be developed before it is put on the street. There is not a plan presented in the report and there should be.

(5) Are all components of the conceptual model realized in the model development?

As developed for a screening process the answer is Yes. However there are several critical areas that should be discussed and evaluated prior to further application:

- Inclusion of reservoir and hydrologic dynamics
- Inclusion of a statistical analysis of results
- Clarification of model application. The parameters, especially the innovation process needs to be explained further
- The model approach has been well done for the level of answer desired. My fear is that the public will rush to conclusions without fully understanding the constraints necessary in interpreting the results or that this was a screening level assessment.

Part III.

(1) Do the model results adequately address all the objectives?

The results address the objective of developing a screening model. The results do not address the cause for the increase temperatures (dams, watershed development, or hydrologic modification). It is clear that something has raised the temperature and it is probably in a priority based on: (1) dams; (2) changes in regimes; (3) watershed impacts. Care should be taken with a screening level study of jumping too far out on the limb.

(2) Do the results properly characterize the uncertainty and variability associated with data collection, source characteristics a model error?

At a screening level model the answer is yes. Additional work should be done however to address the impacts related to the reservoirs, retention time, and statistical significance of the differences in the results.

(3) Are the conclusions reasonable in terms of the model and data uncertainty and variability?

Yes with the caveat that a statistical evaluation of the significance of the difference as related to the model error should be made before the conclusions are made public.

(4) Is the work documented well enough such that others could reproduce the results?

Yes IF the comments made below are addressed.

Overall I feel that the approach, methodology and application was very well done for the level of analysis described. My specific comments included below represent my review of the document and my attempt to make the document more readable to the interested public and decision-makers. My hope is that the document will reach the necessary managers and result in support for expansion of the study to include a more rigorous evaluation of the model, the variability of the system and the application to additional alternatives.

SPECIFIC COMMENTS ON THE REPORT

I. Introduction and Background

The objectives of the report is stated *to assess the relative importance of different sources of watershed impact in respect to changes in the temperature regime of the main stem Columbia River in Washington and Oregon and in the Snake River in Washington*. Three general sources of river impact are identified:

1. Construction of impoundments for hydroelectric facilities and navigational locks.
2. Hydrologic modification to the natural river system as related to irrigation and navigational development
3. Modification of the watershed from agricultural and silviculture practices which reduce riparian vegetation, increase sediment loads and change stream or river geometry.

Ultimately the model will be used by managers and decision-makers to evaluate a decision support system for developing management strategies for attain water quality standards and protect beneficial water uses.

Comments:

- A more complete identification of why this modeling approach is being used as related to the three impacts is necessary.

- How was the decision made to develop this model? Was this an EPA directive? A request from National Marine Fisheries Service (NMFS)?
- The objective of this assessment should be made in the introductory section
- Consider adding a short glossary of important terms

II. GEOGRAPHY, CLIMATE AND HYDROLOGY OF THE COLUMBIA BASIN

Comments:

- One of the sources of impact that this assessment is to address is watershed development. In that case, a more definitive evaluation of the watershed that may affect the water temperature of the study area should be identified.
- Reference is made to *confounding tributaries*. Where are these tributaries and what are the seasonal influence on the overall river thermal integrity?
- Can you prioritize which tributaries in the supporting watershed have the most potential for impacting the results of the assessment? Percentage or location wise which ones need to be concerned about?
- The pre-project hydrology should be identified. This should be in two levels:
  a. Seasonal (monthly) perspective
  b. Daily regime (how much daily fluctuation occurred?
- The post project hydrology regime for high, average and low water years should be presented. This would provide a spectrum of what the hydrologic boundaries. This is important in regards to evaluating the model.
- The seasonal and summer/monthly flow regimes should be identified for the management of the dam complex. This is important in regards to interpreting when the thermal thresholds occurred and how well the model predicted reaching the thresholds.
- An idealized hydrologic regime should be presented for each of the alternatives that the model is expected to be used to evaluate. In this way it can be determined how well the model is matching predicted flow scenarios.

III. WATER RESOURCES DEVELOPMENT

This section of the report needs to be significantly expanded upon to address not only the time of development of the four dams but also what this has meant to the hydrologic and therefore thermal regime of the study area. The broad sense of the Columbia Basin development is addressed adequately however the specific relationship to the project area needs to be discussed.

Comments:

- Expand upon the development of the four study area dams. What impact did they have on the pre-project flow regime?
- Discuss how the dams are operated. Are they operated as run-of-the-river, periodic storage, flood control, navigation, stabilization for downstream releases? Where is water withdrawn at the dams?

- Discuss the physical and limnological effect of water resource development in the project area. Specifically add a section on the limnological relationships that occur as a result of flow regulation. Percentage of the time that stratification occurs? What is the residence time of water within the reservoirs?
- What are the upstream impacts as related to Hells Canyon dam releases? Does it have a seasonal warming effect? What are the input conditions and does it affect the thermal capacity of the study area?
- Are there any impoundments on the tributaries that may be confounding the problem by providing seasonally warmer water?
- A *Biological Relationship* section should be added that identifies the critical biological threshold levels of the primary species of concern in the study area. This is important in that it provides a frame of reference in regards to evaluating the assessment. If the predictions are close to the threshold it is worth putting forth-additional efforts to fine-tune the numbers. If the predictions are not within the proximity of the threshold then not as much effort may be required to assess the trend or direction of the prediction.
- What was the pre-project thermal profile for the river within the study area?
- How was the 20-degree Centigrade level identified? Reference where this came from and what it is supposed to protect. Salmonids? Macroinvertebrates? Humans?

IV. STUDY OBJECTIVES

Comments:

- On Page 5 it is stated that the purpose of TMDL assessment is to:
  - Identify the sources of water quality parameters of concern
  - Identify what if any control or management strategies are possible

It is stated that the temperature assessment models will be used to provide some of the framework for a problem assessment in the mainstem Columbia River. *Is this model ultimately going to be used for the development of the TMDL? If so, how was it determined that this was the best model for use?*

- The objective of the assessment is defined as being to *develop and implement a mathematical model of water temperature for the Columbia and Snake Rivers in a way that is generally consistent with those of the screening model.* That stated, what is the level of detail that is required to address the questions being asked? In other words it should be stated how good the model has to be - within one degree? One level of statistical significance? Etc. The point is that it should be stated what the expectations and requirements are so that we can adequately determine if the model is meeting those objectives.
- Are there any biological or engineering objectives in this assessment?

V. MATHEMATICAL MODEL DEVELOPMENT

This section has five (5) sections. Comments will be separated into the appropriate section.

System Boundaries

- No mention is made of the four reservoirs within the study area and the boundaries associated with them.
- Are the tributaries included within the watershed system boundary?
- What are the hydrologic system boundaries associated with this assessment?
- Figures similar to the "Surface elevations in Lake Franklin D. Roosevelt during 1998" should be made for each of the four reservoirs in the study area over a range of hydrologic regimes. This would help to identify the impacts of flow to the transfer of heat energy.
- Was 1998 a "typical" year hydrologically and thermally at Lake FDR?
- The present baseline boundaries need to be identified for upstream and downstream positions on a seasonal basis.

Thermal Energy Budget

- The statement of *The thermal energy budget has proven to be a useful concept for simulating…..* needs to be referenced. Who has proven it?
- Have studies been done using the Eulerian approach rather than the Lagrangian approach? Where? How successful?
- How are reservoir impacts accounted for in this approach?

Solution Method

- What is a likely range of the Kalman gain matrix-weighting factor? Do large weighting factors connote large potential errors in evaluating the results of the assessment?
- Define the Courant stability criterion (page 10)
- It is stated on page 10 that the mixed Eulerian-Lagrangian method is used in the models. Once the river was subdivided into "N" segments for analysis was any validation done to check to see if the spatial segments provided the constant thermal properties necessary for the solution approach? In other words, once the model time and spatial steps were determined was there any work completed to determine if those assumptions were indeed correct?
- Can a flow diagram of the sequence of operations performed in the solution of the thermal equations be provided?

Time and Length Scales

- Pre-project (development) hydrologic and thermal regimes need to be included in this analysis in order to ascertain the correct time and length scales.
- Was a statistical analysis completed (with the existing data) to determine the variability of the pre/post project regimes? This would assist in determining the time and length step required.

- Is this model only going to be used to evaluate existing operations? Will there not be a need to determine what could be done if the alternative to breach the dams is evaluated?
- What is the source of the geometric data? What is the stream channel variability?

Rationale for Approach

- Have any of the approaches identified on Page 12 gone through review to the level that the conclusion to use the mixed Lagrangian-Eulerian scheme is adequate for the quality of answer needed in this assessment?
- Since it appears that development of the TMDL is a primary goal of this assessment, has EPA defined/recommended the level of detail required?
- Have other models been evaluated as potentially appropriate to this assessment?
- Does the level of effort in this model match the level of quality required for the decision-makers?

VI. DATA SOURCES

Comments:

- Is the quality of the tributary data consistent with the quality of the thermal data compiled by Laenen and McKenzie, 1998?
- Is the thermal data spatially distributed adequately to allow for model evaluation? In other words are there thermal sampling points at locations where the model will be making intermediate predictions?
- How as the information in Table 5 consolidated for use in the model? Were representative sections used or were specific hydrologically important locations selected?
- Was channel roughness considered in the development of the model?
- Are the gaging stations adequately spaced?
- Is solar radiation important to the heat transfer evaluation? If so, was there any solar information collected?
- Was time of water being impounded behind the dams considered in the assessment? What is the retention time of the reservoirs and is there any indication that seasonal, daily of vertical stratification occurs?

VII. PARAMETER ESTIMATION

Comments:

Deterministic Elements = Source term = heat budget + advected thermal units
Travel times of parcels = from system hydraulics

Probabilistic Elements = means and variances of the error terms for the measurement and the systems model*

- Input assumptions should be identified and prioritized as to their potential level of impact

- Data limitations, assumptions, and approximations inherent in the modeling process introduce errors and inconsistencies into the assessment. Accumulated error can lead to the results of the model being unacceptable or incomplete. Based on that statement, the potential error sources for this analysis should be identified.
- The input conditions should be identified.
- How were the three flow levels in the Columbia and Snake Rivers chosen? Are they the boundaries of operation? Averages? High, medium and low flows?
- Do these flow levels represent specific geomorphic constraints? Specifically is the high flow considered in the flood plain?
- Figures 6 through 13 relate to the simulated and observed water temperatures for the period of 1990-1995 for eight dams. In some instances the simulated results do not match the observed for both high and low periods. Is this difference due to lack of data? Does the model have less ability to accurately predict at the high and low ends of the projection?
- The concept of the innovation vector analysis and the application to figures 14 through 21 needs to be explained in more detail. Is this application identifying seasonal shifts in temperature? What does the scale represent (-3 to +4)?
- Figures 22 through 29 are comparisons of actual and simulated innovations. These graphs are hard to read in black and white and perhaps either radically changing the line thickness or using different colors would make them more useful. None-the-less, it appears that the comparison between the observed and simulated is not a good fit. These graphs need to be explained in the result section to help understand their relevance to the evaluation of system model bias and error. Table 11 helps but I really think that the difference between the sample and theoretical variance needs to be explained in relationship to the modeling effort.

IIX. MODEL APPLICATION

Comments:

- How were these three scenarios developed?
- Is the 16-degree Centigrade temperature regime from the tributaries achievable?
- How was the benchmark of 20 degrees Centigrade chosen (page 18)?
- Five areas of issue were identified that require subsequent analysis for future evaluation of Columbia and Snake River temperatures. Can the five areas be prioritized as to their:
    - Level of impact to results
    - Level of impact as related to model calibration
    - Level of statistical importance to evaluating the results
- Was irrigation return flow considered important in the analysis?

- Was reservoir retention and operation determined to be an important component of the heat budget
- Was evaporation considered to be an important element in model calibration?
- Figure 30 through 35 and 36 through 41 are really the essential elements of this assessment. I would suggest overlaying the graphs (to show total change) or developing a table for the differences between the five dams and the frequency of exceedance would be useful for the RESULTS section. I also think an arrow indicating the direction of flow (upstream to downstream) would be helpful for interpretation sake.

IX. RESULTS

Comments:

- Summarize the results with the graphics developed. Specifically it would be useful to overlay figures 30-32, 33-35, 36-38, 39-41. In this way each of the scenarios can be addressed with specific reference to changes predicted.
- Develop specific headings for each of the three scenarios and identify specific graphics (see above) to assist in evaluating them.
- A discussion on the model error as related to the results should be developed. Are the results statistically valid?
- Are the results for levels of exceedance within the statistical ability of the model? Specifically is a 1.4 degree variance at Grand Coulee dam supportable with the level of effort in a screening model? The point is it is that it might not be the actual number that is appropriate but instead be the trend that is seen. With the level of error imbedded in the coefficients and in the model-input data, it might not be safe to say that the actual change is 1.4 degrees. Instead it might be more appropriate to indicate that a thermal increase occurs and exceeds the threshold for specific salmonid species and life stages.
- Did the models perform as you hoped or was there a need to manipulate the coefficients to allow the model to balance?
- No discussion is included on how good the model did versus the actual temperatures. This should be a separate section on Model Validation in the result section. The results of the modeling are only as good as the model predictions.
- A separate heading on the results from figures 30-35 and a table would be helpful.
- A separate heading on the results presented in figures 36 - 41 and a table of results should be developed. Specifically in addressing whether the changes what are documented between 36 and 37 are statistically significant.
- When do the results exceed the 20-degree Centigrade threshold?
- How much natural (pre-project) variability can explain away the thermal increases (without dams) that is predicted?
- What figure 39 tells me is this:
  - Water warms as it goes downstream

- There is a thermal jump at McNary dam and this is due to the Snake River influence
- There is a thermal jump at McNary without the four dams on the lower Snake River

WHAT IT DOES NOT TELL ME is how significant the thermal difference is and if the model is good enough to believe.

X. CONCLUSIONS

Comments:

- The conclusions are supported by the data presented.
- A DISCUSSION section should be included here to help interpret the results and conclusions drawn.
- Questions arise as to the level of detail of the model results as related to the changes identified. For example, is the model sensitive enough to allow for percentages as low as 1-3% to be valid? No results were presented that evaluated the level of change in model results that could be realized with small incremental changes in the model parameters. A section in the conclusions on the Model should be developed. This section would address how good you feel the model is as related to the applications.
- Is the 1-3% increase due to Snake River dams (conclusion 3) due to upstream Snake River dams?
- What is the level of error associated with the results and the therefore the conclusions?
- Are there limits to the use of this model based on the results presented? My fear is that without identifying some limits anyone may think that it is applicable. For protection sake it might be wise to address future uses of the model (i.e. limits, assumptions, etc.)
- Is a conclusion that the reservoirs increase the thermal condition in the river? If so then the reservoirs are indeed heat sinks and even though they may be run-of-the-river they do have an influence on the thermal character of the river. Therefore I strongly urge that you include (as I stated earlier) a section on reservoir dynamics.
- A discussion on the changes that occur at McNary as a result of Snake River inflow would be helpful.